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A SIGNIFICANT CHANGE TO THE SATELLITE DATA ARCHIVING SYSTEM *(SDAS)*

by
M. Connelly

ATMOSPHERIC ENVIRONMENT SERVICE

DOWNSVIEW, ONTARIO

1990

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M. Connelly

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Abstract:

The Satellite Data Archiving System and its products are described. Its initial configuration and the subsequent changes to May, 1989 are discussed. The advantages of the current configuration, which includes a new frame synchronizer, are described. The frame synchronizer is examined and the great potential that it provides is discussed at some length.

Résumé:

On décrit le système d'archivage des données satellitaires ainsi que ses produits connexes. On discute de sa configuration initiale et des changements qui y ont été apportés depuis le début du système jusqu'en mai 1989. On décrit les avantages de la configuration actuelle qui inclut un nouveau synchroniseur de trame ("frame synchroniser"). On décrit ce qu'est le synchroniseur de trame et le potential qu'il offre.

1. The Satellite Data Archiving System

The Satellite Data Archiving System (SDAS) was implemented in order to fulfil Canada's obligations to the International Satellite Cloud Climatology Project (ISCCP), which is being run under the auspices of the World Meteorological Organization (WMO). Canada's obligations include regular submission of sets of data received from the Geostationary Operational Environmental Satellite (GOES) East whose position over the equator is normally at 75°W.

The following description refers to the situation in May, 1989. Small changes have occurred since then but the overall facts remain the same.

1.1 Products Required by the ISCCP

The ISCCP requires that the full-earth images transmitted from the satellite be ingested every three hours. From the raw data thus acquired, which comprise some 220 million bytes on disc, a primary product is extracted, namely an 8 by 8 km. resolution subset of both the infrared (IR) and visual (VIS) datasets contained in the raw full-resolution data. Each primary product file comprises about 10 million bytes. The system's disc capacity is sufficient to house 46 of these files before space is exhausted. 46 such files house almost six days' of data, eight files being produced each day.

Every six hours, at the synoptic times, the most recent primary product file is extracted and sent to the Numerical Weather Prediction Model in Montreal where the data are used operationally.

The 46 primary product disc files are filled one after the other in a cyclic fashion and, in order to avoid previous data being progressively overwritten and therefore lost, these files are periodically drained to magnetic tape. The resultant tapes are retained in an archive in AES (CCAA) and copies are sent to the Global Archiving Center of the ISCCP in Washington, D.C.

From each tape of primary product files, secondary products are extr-

acted, comprising a further resolution reduction subset of the primary products, viz. a 32 km. by 32 km. resolution image of both IR and visual data. The secondary product files are housed on disc and drained to tape on a monthly basis. The resultant tapes are sent to the Global Processing Center of the ISCCP in New York City. An archive of these products is not maintained in AES although the last two months' are always available.

According to a predetermined schedule, the system is required to ingest full-resolution data for an area less than that of the full-earth image. The required area is centred over the subsatellite point. From this partial-earth image, calibration data are extracted and stored on disc. Such calibration datasets are required about five times a month, and at each month's end they are drained to tape and saved in the AES (CCAA) archive. Copies of these calibration datasets are sent to the Satellite Calibration Center (SCC) of the ISCCP in Lannion, France. Each calibration data set is about 24 million bytes in size.

1.2 SDAS System Hardware

The SDAS system is based on a Data General Eclipse MV 4000 computer. It has 4 megabytes of immediate access working memory and more than one gigabyte (a billion bytes) of virtual memory assigned equally to three Winchester discs. It is equipped with a single 6250-BPI tape drive, as well as an optical disk drive which has not yet proven to work satisfactorily.

The SDAS system hardware is illustrated in Figure 1.

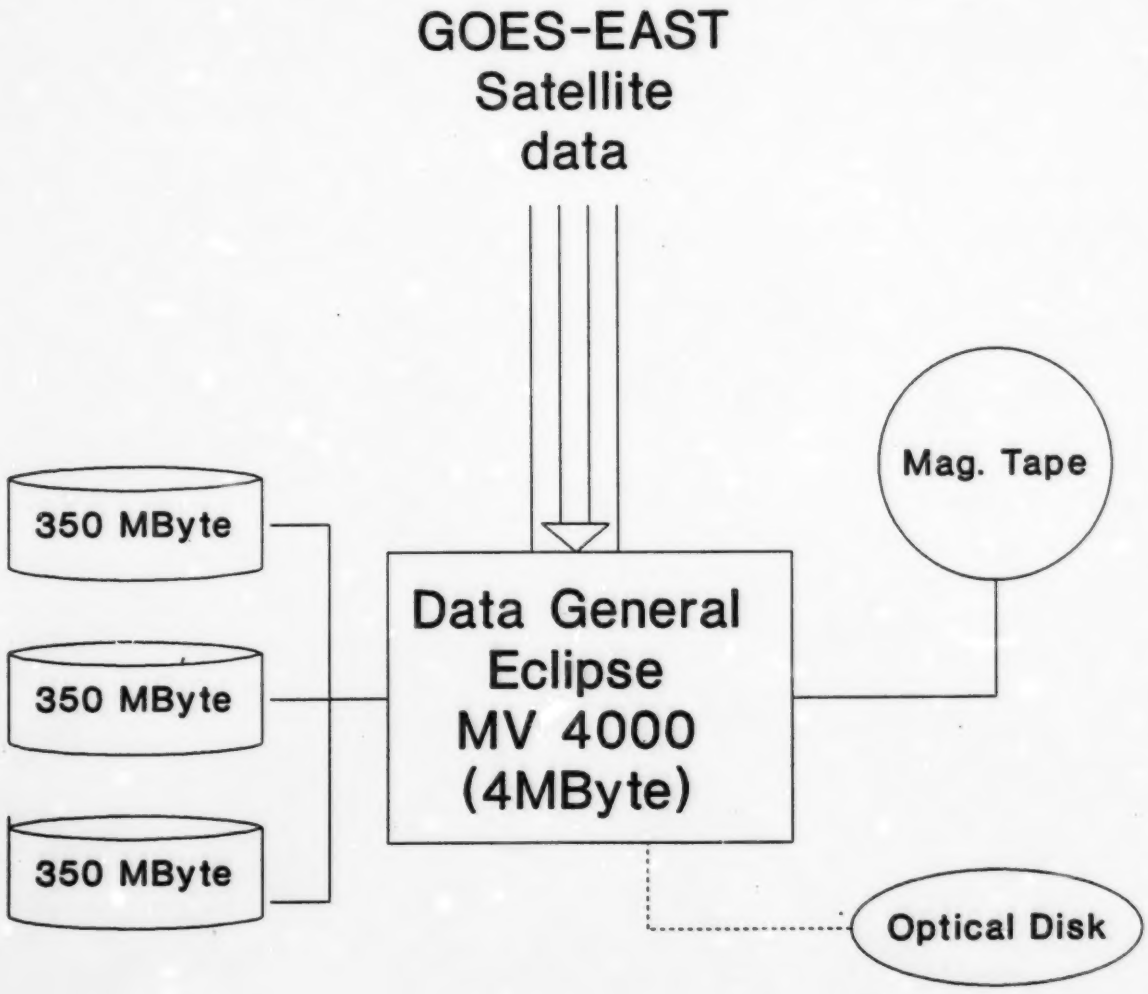
1.3 The availability of GOES East satellite data

In late 1982, when SDAS was first seriously discussed, the only source of GOES satellite data available in AES Headquarters was provided by the GOES satellite receiving system in the Satellite Data Laboratory (SDL). This is shown in Figure 2.

This system is also based on a Data General Eclipse computer and receives satellite data from a device known as a frame synchronizer. This frame synchronizer is under direct control of the computer, which can start it, command it to pass data only when a particular scan has arrived, and stop it. Handshaking logic between the computer and the frame synchronizer contributes substantially to the latter's complexity.

Figure 1

Satellite Data Archiving System (SDAS)



2. General characteristics of the data from the GOES weather satellites

Before explaining how the SDAS system is set up it may help to consider some of the general characteristics of the data transmitted from the GOES series of weather satellites, namely:

- the pattern of transmission is repeated every half hour

- imagery is transmitted as a series of west-to-east scans of the earth's disc as seen from the satellite. The scans begin in space over the north pole and end below the south pole. One hundred scans are sent every minute. Eighteen hundred scans suffice to cover the whole earth, so that eighteen minutes are taken up by image transmission every half hour.

- the signal is a broadcast signal beamed down to cover the full face of the Earth, where the data arrive at all points in direct sight of the satellite.

- the transmission from the satellite cannot be stopped, slowed or changed in any way by any user-receiving station. Only one station on the ground can control the satellite's action - the control centre station near Washington, D.C.

- the transmitted signal is digital, composed of a single stream of bits, arriving at a frequency of about 2.1 million bits per second.

- the imagery and other required data within the single stream of bits are arranged in blocks that are separated by time gaps. These gaps contain data that allow the receiving equipment to lock on to the start of each block.

- the data in the stream are altered as follows before being transmitted to ensure that transmission occurs with a minimum of error:

- every alternate eight bits are complemented

- pseudorandom noise is superimposed on the resultant stream of complemented data, thereby scrambling it to some extent

- differential coding is added to the scrambled, complemented data

- the signal is then modulated for transmission (and therefore must be demodulated on receipt)

3. The significance of the frame synchronizer

From the above discussion it is evident that the signal, even after demodulation, cannot be easily reconstituted directly by computer software if this is to be done as the data arrive. Software is too slow. The job must be done by hardware which is markedly faster than software. The necessary hardware logic is housed in the frame synchronizer.

Essentially, the frame synchronizer renders the incoming data sensibly acceptable to the computer by:

- removing the differential coding from the signal
- removing the pseudorandom noise, effectively unscrambling the data
- de-complementing each alternate eight bits

and thus recovering the original data. Most frame synchronizers also

- parallelize the data; in this case, into a 16-bit parallel output
- pack the data as efficiently as possible into the output word. Thus 9- or 10-bit elements are packed (not very efficiently) one element per output word, while 6- or 8-bit elements are packed two per word.

These operations occur at a speed sufficient to accommodate an incoming data rate of more than two million bits per second. When the data, duly parallelized, have been fully reconstituted, they are passed on to the computer.

a. GOES-1

As mentioned, the SDL GOES receiving system was the only source of GOES satellite data in AES HQ at the time SDAS was first seriously planned. That system, shown in Figure 2., functioned, and still functions, as follows:

- it ingests only the first (northernmost) third of the earth image data every half hour and writes them to disk. This process takes about 6 out of every 30 minutes.
- it produces images from the disk-held data and sends them out on communication lines to serve the needs of remote users.

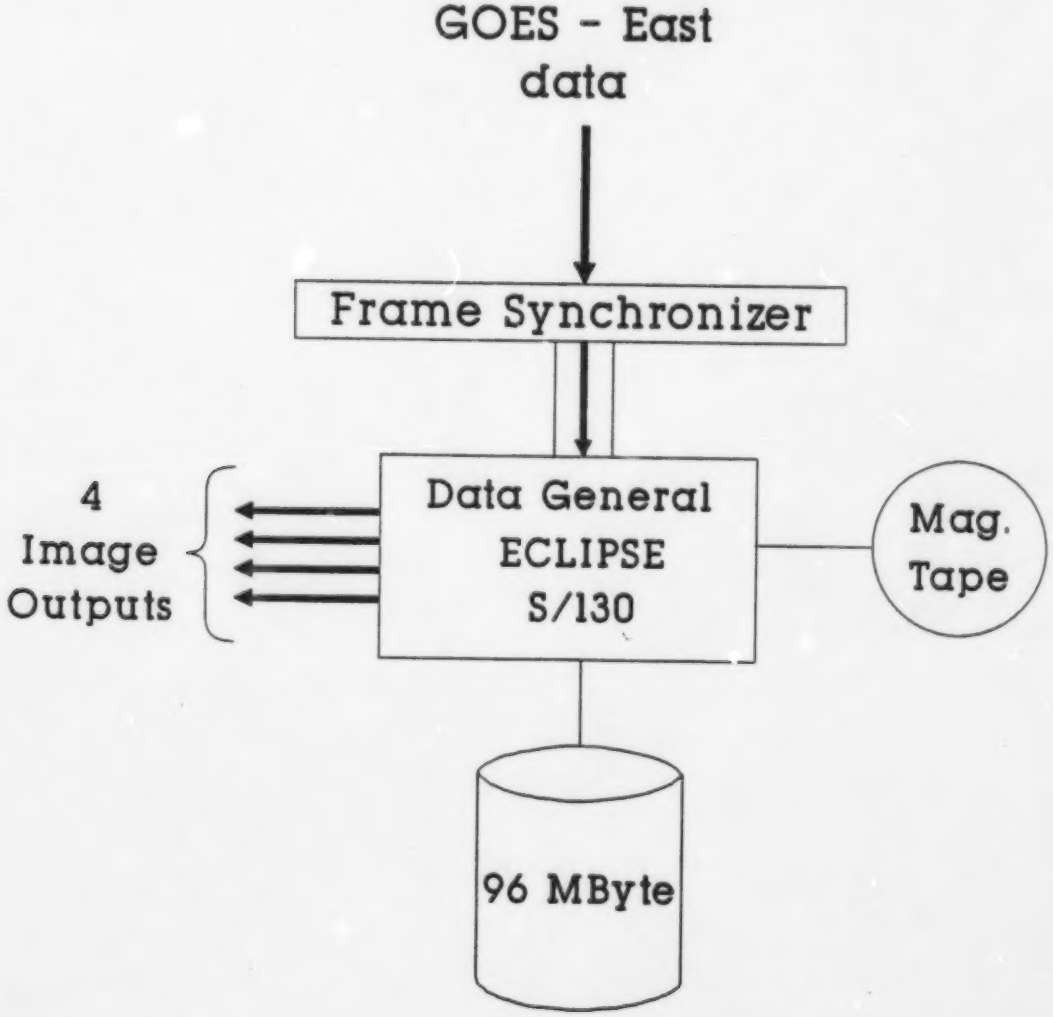
Throughout its 30-min. operational cycle, the GOES system is extremely tight on time. There is absolutely no possibility of adding any further computing load; to satisfy SDAS or any other system.

In contrast, the needs of SDAS are quite different. As mentioned, it needs the full earth view, i.e. data ingestion for 18 out of the 30-min. cycle, although it needs this input only every three hours.

Figure 2

Satellite Data Laboratory (SDL)

GOES Receiving System



5. GOES-2

Because of the fundamental differences between the requirements of the GOES and SDAS systems, considerable changes had to be made in the Satellite Data Laboratory to satisfy the needs of SDAS. The changes involved building a brand new system that duplicated the functions of the SDL GOES system while simultaneously serving the SDAS system with its 18 min. of data every three hours.

The new GOES system, which came to be known as "GOES-2" in the SDL, comprises twin computers. One of these (the frontend computer) serves only to ingest data, store them on the disk it shares with its twin (the backend) computer and simultaneously send the ingested data across a fast computer-to-computer link to the SDAS system. The GOES-2 system is shown in Figure 3. The original SDL GOES system, which continues in use to this day, quite naturally assumed the name, "GOES-1".

GOES-2 ingests data for 6 minutes at the start of each half hour, stores them on disk and offers them at the same time to the SDAS link. If SDAS needs data, they are sent across the link. After 6 minutes have elapsed the GOES-2 frontend computer hands the disk across to its backend twin while continuing to send data across the link to SDAS (if SDAS needs data). The backend proceeds on its own for the balance of the half hour producing the batch imagery which is the normal product of both SDL GOES systems.

The GOES-1 and GOES-2 systems are shown together in Figure 4.

It is evident that SDAS relies for its data directly on the GOES-2 system, specifically on its frontend computer. At the time the system was inaugurated this dependence was considered unavoidable.

Figure 3 The GOES-2 System in the SDL

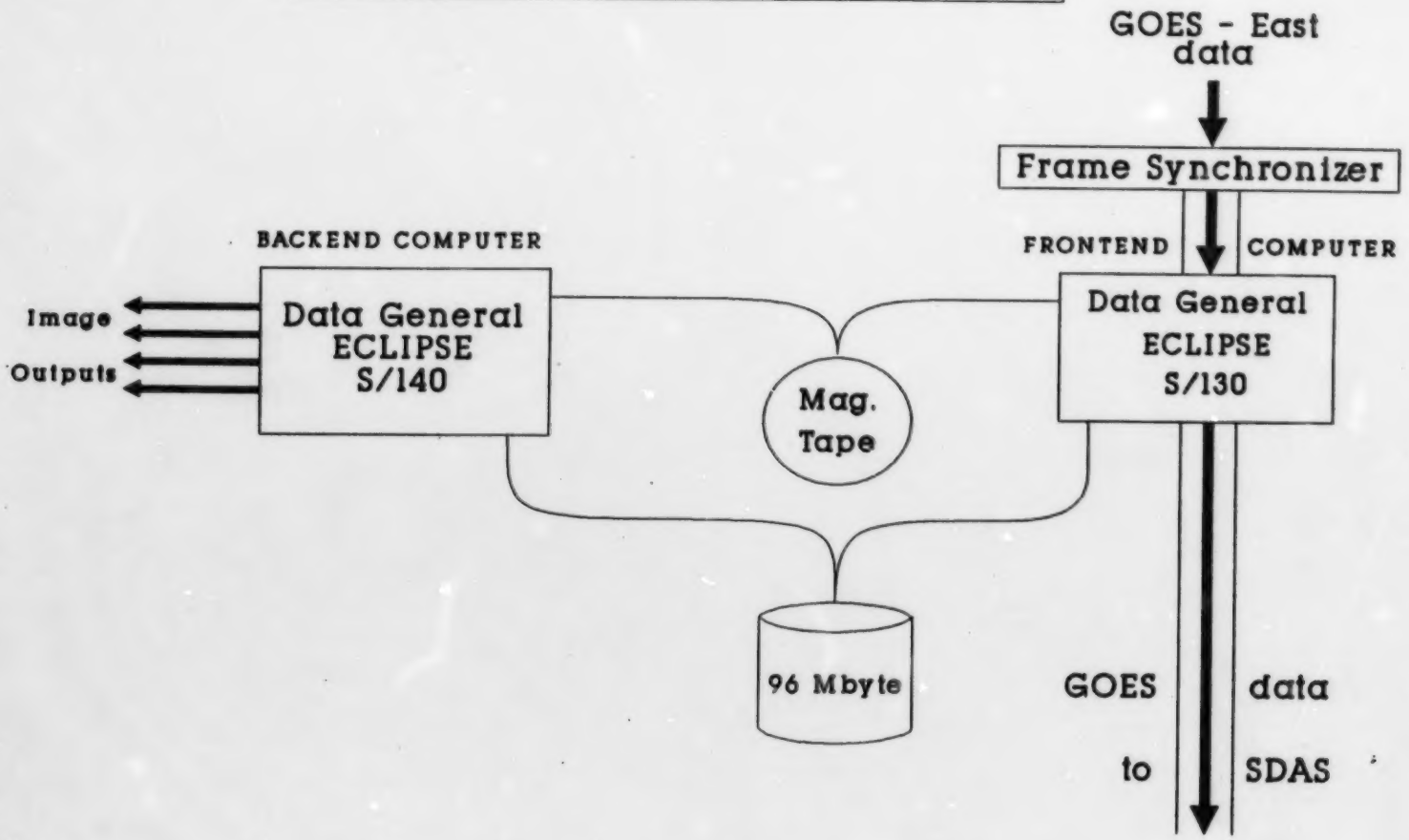
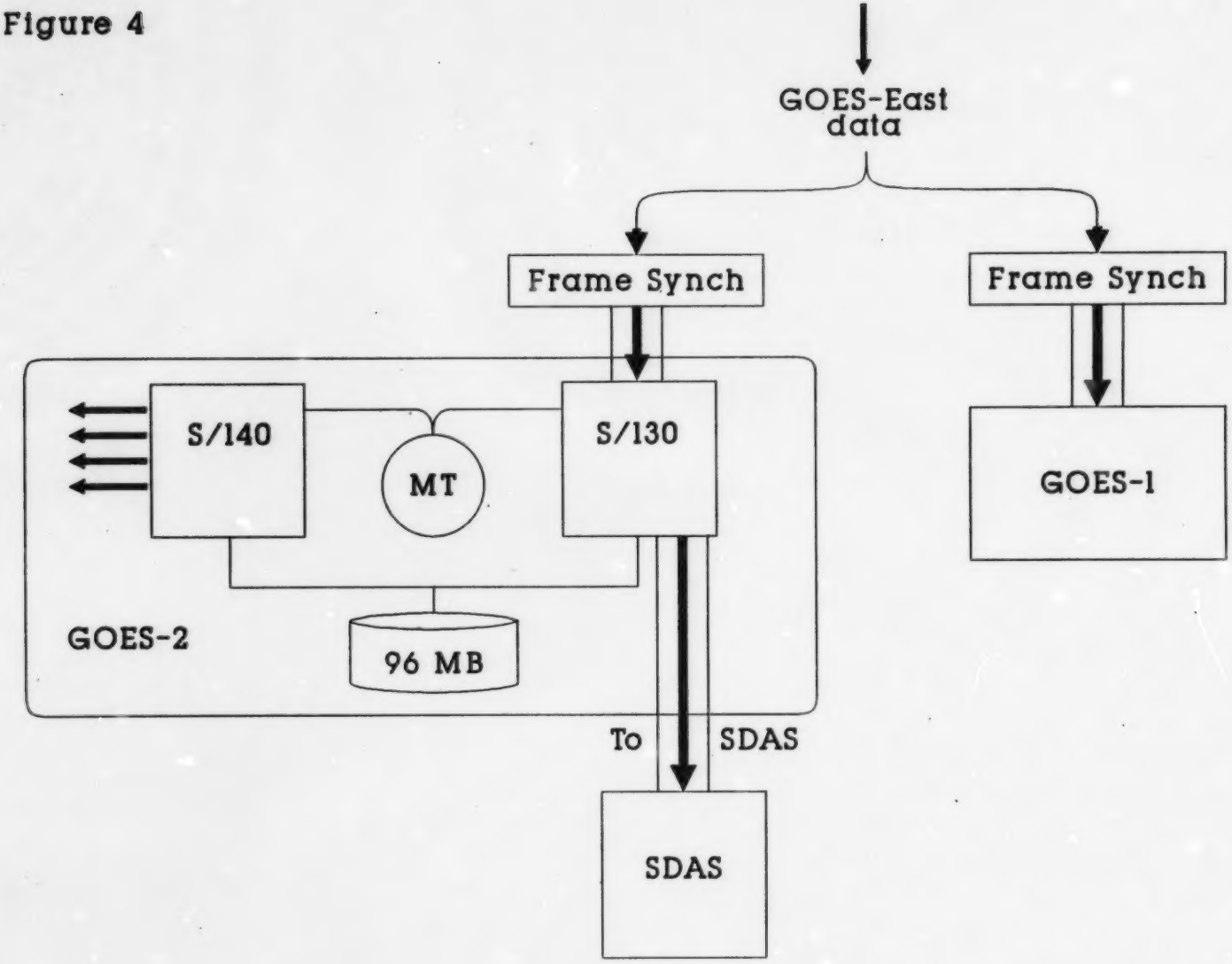


Figure 4


GOES-East
data
Frame Synch
Frame Synch
S/140
MT
S/130
GOES-1
GOES-2
96 MB
To
SDAS
SDAS

6. Data Transmission Format changes

Conceived in 1982, SDAS first became sporadically operational in 1984 and fully operational in March, 1987. Its first configuration made it totally dependent on the correct functioning of the GOES-2 system which was run under the control of the Satellite Data Laboratory.

From 1982 until 1987 the data transmitted from the GOES East satellite were in a format known as Mode A. SDAS, and the two GOES receiving systems, were designed to handle this format. A new, more efficient format known as Mode AAA was implemented operationally on a routine basis for the GOES East satellite in March 1987.

The Mode AAA format contained everything the Mode A Format had contained plus a lot more.

Significant differences between the Mode A and the Mode AAA formats included changes in the transmission frequency, the number of data blocks per scan, the amount of dead time and the addition of dwell sounding data. Table 1. compares major characteristics of the two formats.

Table 1.

Differences between Mode A and AAA formats from the GOES East satellite

Characteristic	Mode A	Mode AAA
Transmission frequency	Two frequencies: 524 Kbs for IR data 1.747 Mbs for VIS data	All data sent at one frequency of 2.1 Mbs
Data blocks per scan	9	12
Dead time per scan	15%	None
Dead time per 30 minutes	12 min.	None
Dwell sounding data present	No	Yes, for the last 12 of each 30 min.
No. of bits per IR pixel	8	10

Ample warning about the change from Mode A to Mode AAA format was given to all users, along with comprehensive documentation about the new format, so that they could arrange for the necessary changes to their individual systems.

A similar situation exists now, because the Mode AAA format is due to be superseded by another, yet more efficient, format known as GVAR (or GOES-NEXT) in less than two years' time.

7. The MAGIC Box

To accommodate the change from Mode A to Mode AAA Format, management decided to acquire a complex (and very expensive) piece of hardware called a MAGIC Box and install it, together with a new frame synchronizer, ahead of the GOES receiving systems in the chain of equipment leading to SDAS. The MAGIC Box strips from the Mode AAA data all components except those which make up the Mode A format. The reconstituted Mode A data are then passed to the original GOES systems and, ultimately, to the SDAS system; thus keeping them all running. See Figure 5.

SDAS was now extremely dependent on what had become a long and complicated chain of equipment, any component of which, if it failed, would inevitably result in the failure of SDAS. This SDAS vulnerability was considered by management to have become critical and was seen as placing the system in altogether too much jeopardy. Further, the SDAS system and, incidentally, both of the GOES receiving systems were denied any benefit that might result from having Mode AAA data, since they received only the reconstituted Mode A data.

Because of the above imposed or inherited liabilities and limitations, it was decided to render the SDAS system far more robust and reliable, bypassing as much as possible of the long chain of equipment on which it depended.

To bypass all components in the chain, a new frame synchronizer was installed and the resultant Mode AAA data were fed directly to SDAS; see Figure 6. The new configuration is shown somewhat differently in Figure 7. where the chain of components which are bypassed is removed. This illustrates very well the new simplicity achieved by the new device.

This new, simple configuration has been fully operational in the SDAS system since January 1, 1989. The new frame synchronizer costs $10,000 US.

Figure 5

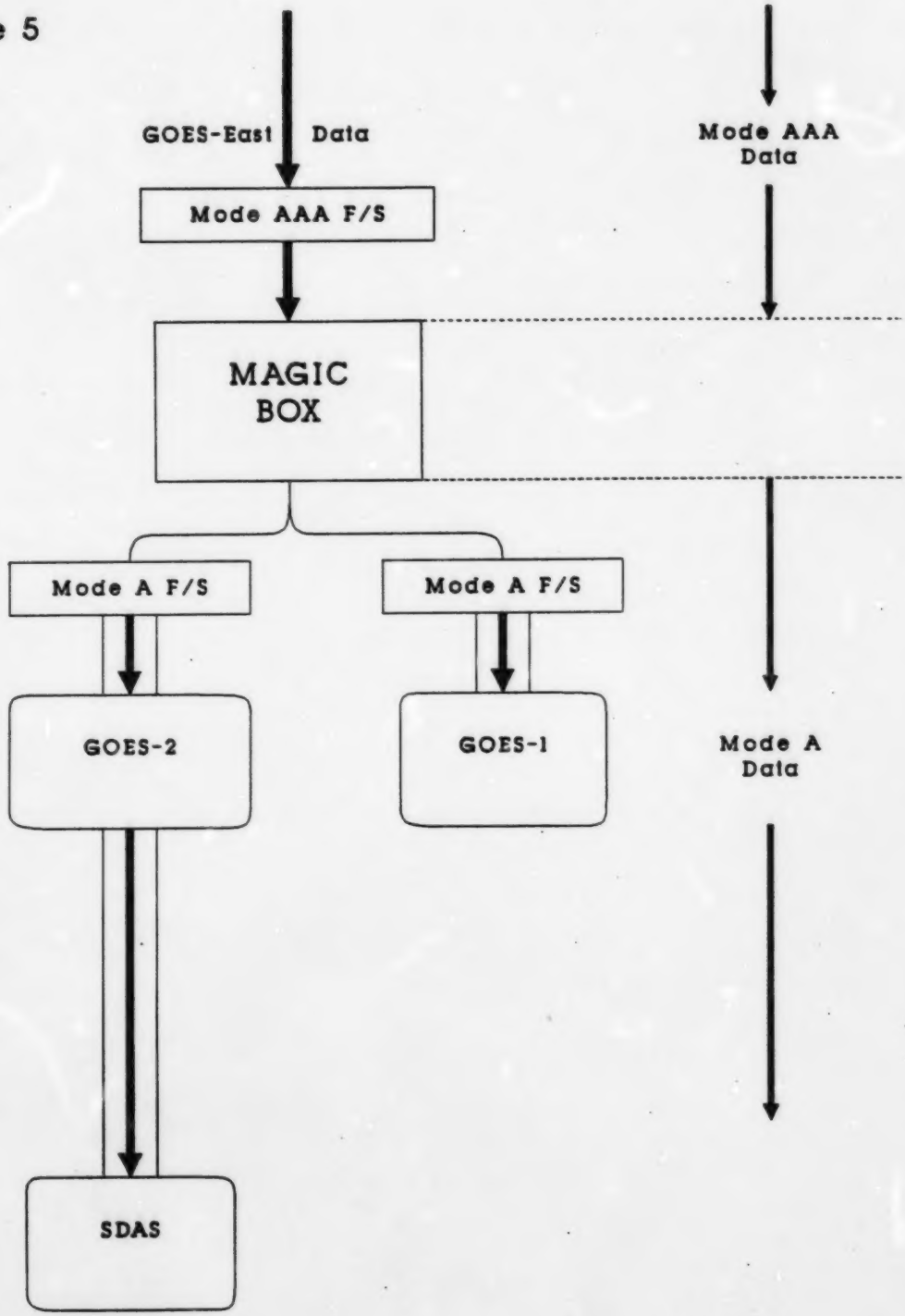

GOES-East Data
Mode AAA F/S
Mode AAA Data
MAGIC BOX
Mode A F/S
Mode A F/S
GOES-2
GOES-1
Mode A Data
SDAS

Figure 6

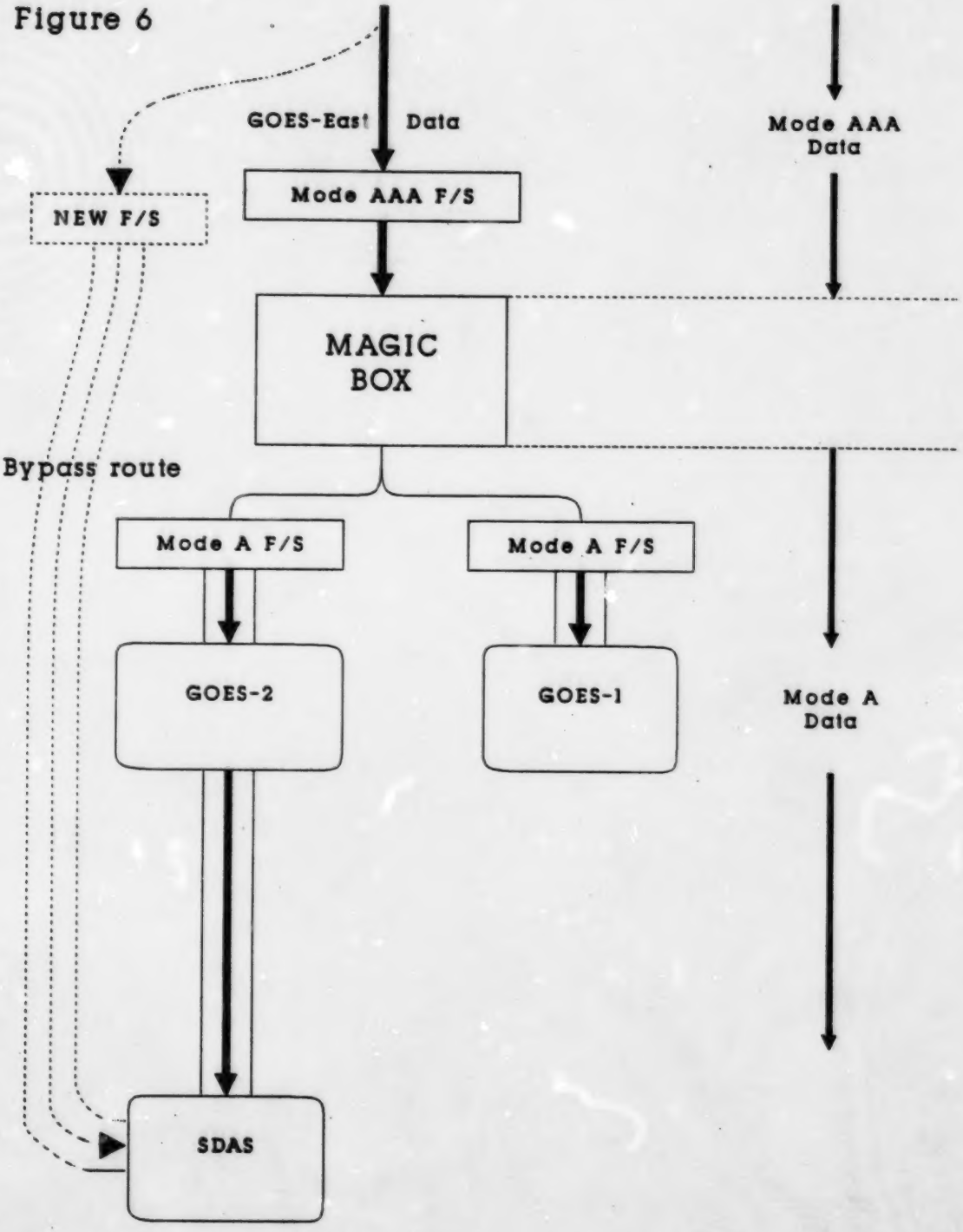
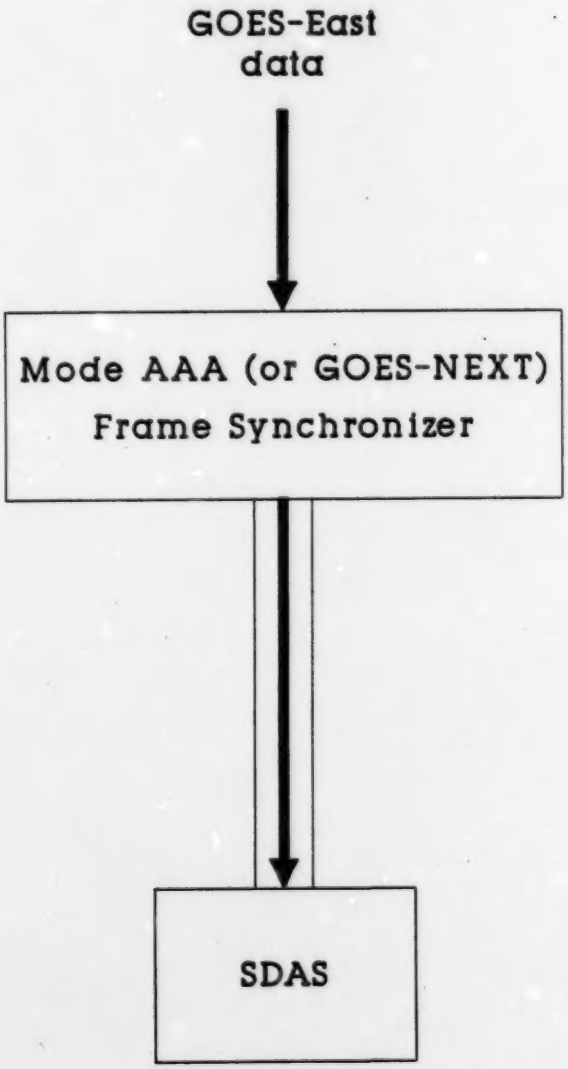

GOES-East Data
Mode AAA Data
NEW F/S
Mode AAA F/S
MAGIC BOX
Bypass route
Mode A F/S
Mode A F/S
GOES-2
GOES-1
Mode A Data
SDAS

Figure 7


GOES-East
data
Mode AAA (or GOES-NEXT)
Frame Synchronizer
SDAS

8. Factors contributing to the success of the new SDAS configuration

There are two principal reasons why the changes mentioned above could be made to the SDAS system. The first is the capability of the computer to support a user-customized General Purpose Interface. The second is the versatility and simplicity of the new frame synchronizer.

- The General Purpose Interface

The Data General series of Eclipse computers, both the early ones, viz. models S/130, S/140 and S/280, and most of the range of MV virtual memory Eclipse machines, support a General Purpose Interface that can be customized to accept a variety of inputs (or to generate various outputs). This, along with the ability of the user to program at the interrupt level, allows these machines to ingest the data from the new frame synchronizer.

- The new frame synchronizer and its output bus

The frame synchronizer itself is driven by the incoming data. For example, it recognises the synchronization sequence preceding each block of data and removes it, leaving a convenient time gap of 4.8 ms between successive blocks. It also determines the length of each block of data as it arrives, taking two data control words that are right at the beginning of the block and using them to alter its own processing. These two words contain the number of data elements in the incoming block and the size of the elements, in bits. The product of these two pieces of information gives the frame synchronizer an exact count of the number of bits that are to be ingested for that block. Thus the frame synchronizer is continually adapting itself to the changing flow of blocks coming from the satellite. A full description of the frame synchronizer can be found in the bibliography, reference 1.

(Because the forthcoming GVAR transmission will have the same synchronization sequence and the same two crucial items of information at the start of each data block, we can say with full confidence that the frame

synchronizer will be able to ingest the GVAR data just as easily as it does the Mode AAA data.)

The frame synchronizer output is carried on 40 parallel lines that comprise the GOES Data Acquisition System (GDAS) bus. Of these lines 16 carry the data while others carry various control signals. One is a clock signal, essential for strobing data from the bus, and another carries a "start-of-block" signal. These 18 (16 data plus 2 control) lines are the minimum needed to customize the general purpose interface for an Eclipse computer so that it will accept the full data stream from the GDAS bus.

Other control lines are in the GDAS bus. One, carrying "end-of-block" information, may also prove very useful for the ingest of blocks whose sequence is unpredictable, which will occur with GVAR data.

The Broadcast nature of the GDAS bus

What the frame synchronizer puts on the GDAS bus is determined solely by what it receives from the satellite. No control over its action is exerted by SDAS or any other system. There is in fact *no practical* way that any system receiving data from the bus can affect either the bus or the frame synchronizer. As far as the bus and the frame synchronizer are concerned the SDAS system may as well not exist, for they are totally oblivious to its presence. The only thing that the frame synchronizer knows is that it passes data to the bus; and the only thing that the bus knows is that it is carrying data that it received from the frame synchronizer.

Seen from the other perspective, i.e. from the SDAS system's point of view, the same thing can be described by saying that it, SDAS, is powerless to do anything to the bus apart from reading (or not reading) its data. SDAS has no ability to start, stop or slow down the traffic on the bus. Nor can it acknowledge any data that it has read because the bus is completely indifferent to SDAS and all its doings. Only by passive acceptance of what is being transmitted along the bus can SDAS survive.

The essential indifference of the frame synchronizer and bus to the system(s) which they supply with data is of paramount importance. To appreciate the possibilities of the GDAS bus it must never be forgotten that the data flow along it is one-directional and that no action from receiving systems attached to the bus can affect this flow in any way. In other words, the data on the bus are merely being broadcast. Because of the broadcast nature of transmission along it, the bus has great potential. Being totally unencumbered by SDAS, or any other receiving system, the bus is completely free to function regardless of the number of receiving systems that may be reading its data.

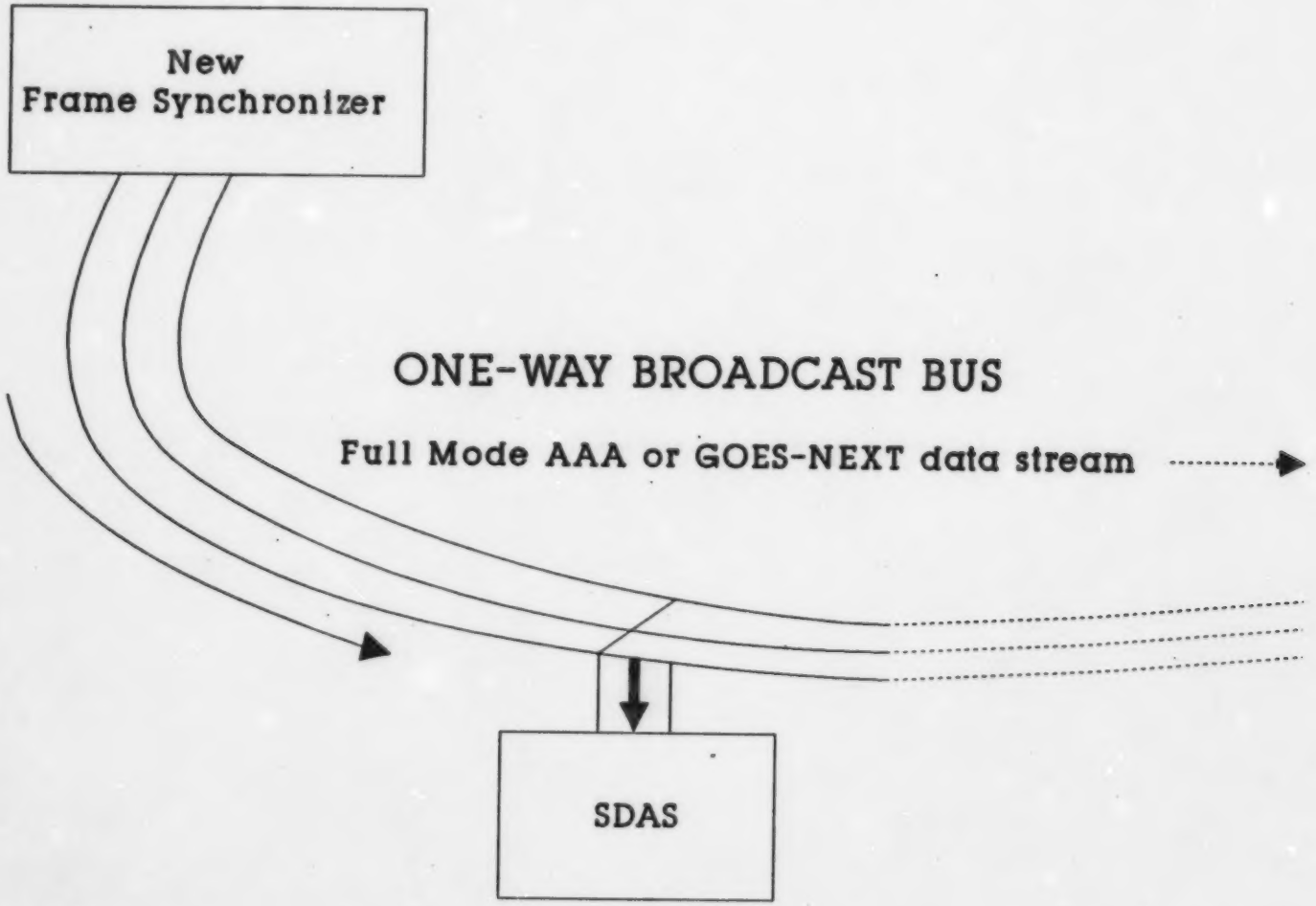
Thus the bus can be employed to supply the full data stream from the satellite simultaneously to any number of receiving systems. It is up to each

system to determine how much or how little it chooses to read from the bus.

Viewed from this "broadcast" perspective the present configuration of the SDAS system is better seen as just one of any number of other systems tapping the data that are available on the bus. See Figure 8.

An incidental benefit of the relative simplicity of the frame synchronizer is that it has no need to be alert to possible prompts and warnings from from the GDAS bus. This greatly reduces the requisite logic within the frame synchronizer itself, thereby reducing its cost of manufacture. Thus its construction is far simpler than, say, the Mode A frame synchronizer which must be able to react to signals coming from the computer that it supplies with data.

Figure 8


New
Frame Synchronizer
ONE-WAY BROADCAST BUS
Full Mode AAA or GOES-NEXT data stream
SDAS

Practicalities

- Disseminating the data

In theory the frame synchronizer and the GDAS bus can supply an infinite number of systems with the full complement of satellite data. In practice, however, some limitations must be considered.

The frame synchronizer is equipped with a relatively short ribbon cable carrying the parallel output. This cable is the GDAS Bus and is only about 25 feet long. It is furnished with a single connector for passing the data to just one computer system. To spread the data more widely the bus evidently needs some modification.

The output speed of Mode AAA (or GVAR) data coming from the frame synchronizer is a maximum of 220,000 16-bit words per second, viz. one tenth of the bit rate of the data coming from the satellite. To push this signal further it is necessary to boost it and place it on a longer cable and to equip that cable with plugs from which other computer systems can draw the data.

There are two ways of extending the bus to supply several, more remote users. One is simply to continue the parallel transmission, after boosting the signal, along another ribbon cable. The other is to re-serialise the data and to send it along a single fibre, preferably optic; thus creating a serial bus.

Major advantages of a parallel bus are simplicity and a relatively low transmission rate; the data remaining in a format ideally suited to a receiving computer. Disadvantages include the high cost of flame-resistant ribbon cable and the relatively short distance, despite the low transmission rate, that the electrical signal can be transmitted (perhaps 400 feet) before deteriorating and needing additional boosting.

Advantages of a fibre optic serial bus include the relatively cheap

cost of flame-resistant cable and the great distance over which the signal can be sent without loss of integrity. This distance is perhaps several tens of kilometres which opens up the possibility of the bus supplying data to users well outside the building. Disadvantages include the requirement to serialize the data before putting it on the bus and to reparallelize it after taking it off.

To tap the data on the bus, plugs must be devised and installed in the bus in those places where the signal is needed. These will necessarily differ in mechanism depending on the type of bus, parallel or serial, which is present.

- Picking up the data

As already mentioned, the technique for picking the data off the bus has been resolved for Data General Eclipse computers. The interface requirements and the software to drive them are defined and available.

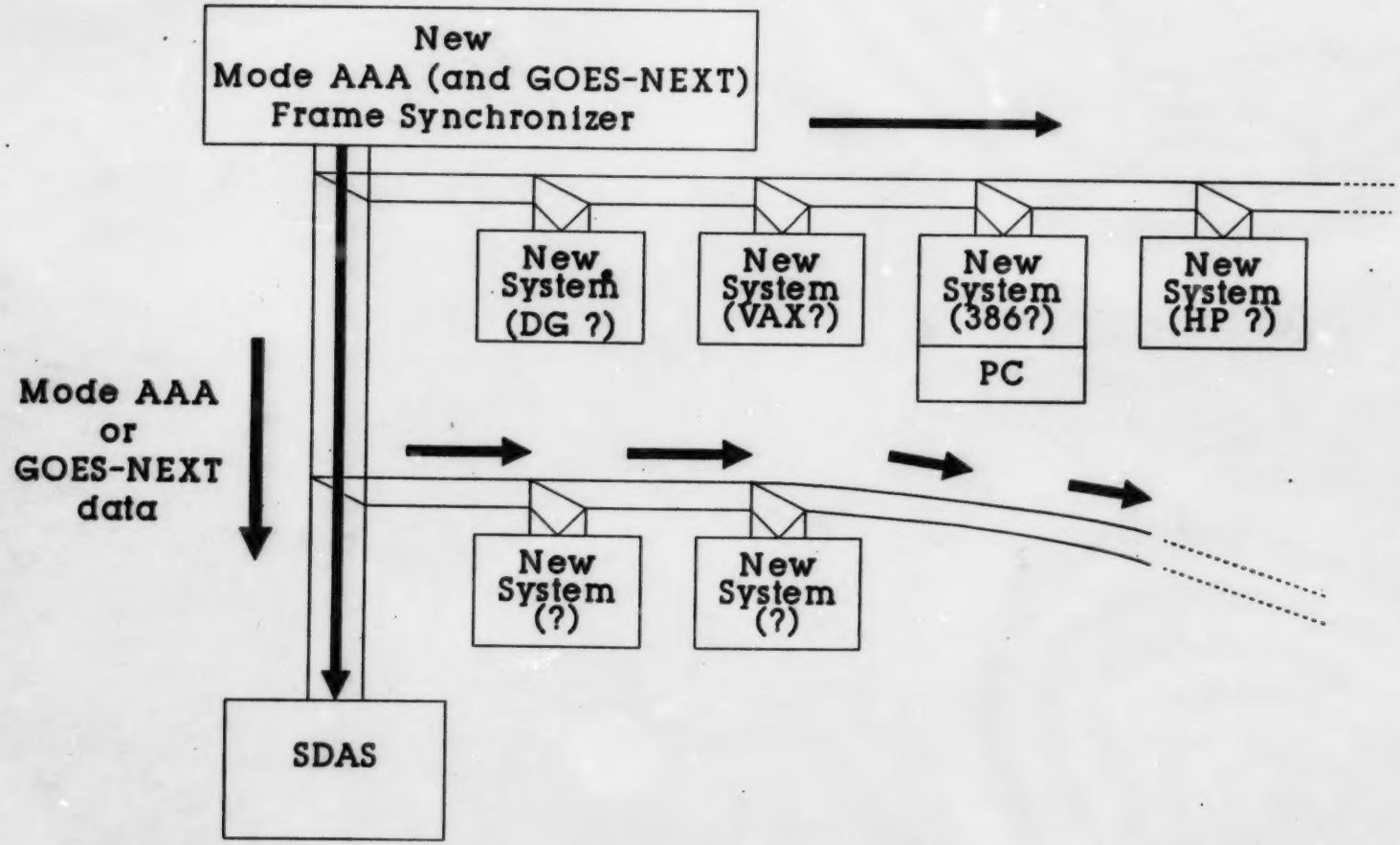
Another machine that has been used to access the bus data is the Model 386 Microcomputer, which is used fairly widely as a frontend device by several different manufacturers of personal computers. This opens up a wide range of affordable computers to those who wish to access the satellite data. One such machine is the Compac 386 Personal Computer used in Climate Hydrometeorolgy and Marine Division where the data would be welcome.

Access has also been implemented for DEC MicroVAX computers, although the operating system used with these machines can prove a stumbling block. Even so, and probably because the frame synchronizer was first used with DEC equipment, additional control lines are included in the bus solely for the purpose of facilitating the link to MicroVAX machines. The link is indirect, passing through a device separately available and known as a GDAS Port. This port then interacts, in a handshaking mode, with a DRV11-WA DMA interface to the MicroVAX.

Doubtless there are other machines capable of accessing the data on the bus. The specifications of the bus allow any machine to be investigated for its capability to access the data. A possible configuration with several different machines hooked to the bus is shown in Figure 9.

Figure 9

Potential proliferation of Satellite systems



Summary

The Satellite Data Archiving System (in Climate Data Management Division) which for years was heavily dependent for its data on a chain of computers and other equipment beyond its control, has been freed from this dependence. Freedom is achieved by taking the data directly from a point much closer to the satellite receiving antenna itself, thus bypassing almost all of the previously intervening chain of equipment. A new frame synchronizer enables the bypass to succeed and is fully capable of receiving the GVAR signal when it arrives.

Conversion of the Mode AAA signal to the Mode A format, required by the archiving system, is performed as the data are arriving.

The output of the frame synchronizer is a parallel stream of data that is broadcast on its output bus. This arrangement opens the door to a potentially unlimited number of ingest systems all accessing the data at the same time. The bus carrying the full complement of satellite data can be extended considerable distances to serve its client systems.

Bibliography

References

1. GOES Data Acquisition System, GDAS Interface Hardware, Design and Operations Manual. K.J.Leap & K.E.Plattner, PROFS Heterogeneous Data Integration, NOAA/NESDIS, Boulder, Colorado

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- Harry Lamb, Technology Support Division
- Athus Pantos, Pantos Technologies Inc., designer and builder of the customized hardware interface for the Frame Synchronizer
- Peter Ting, Data General, writer of the software driver for the interface

Glossary of Acronyms

AES - Atmospheric Environment Service

CCAA - Canadian Climate Centre, Archives, Data Management Division, AES

GDAS - GOES Data Acquisition System

GOES - Geostationary Operational Environmental Satellite

GOES-1 - The first GOES data receiving system in the Satellite Data Laboratory

GOES-2 - The second --------- ditto ---------

GOES-NEXT - The next GOES transmission format after Mode AAA (same as GVAR)

GVAR - GOES variable-length block transmission format (same as GOES-NEXT)

IR - Infrared

ISCCP - International Satellite Cloud Climatology Project

MAGIC - Mode A GOES Image Converter (as used in 'MAGIC Box')

Mode A - The GOES transmission format before March, 1987

Mode AAA - The GOES transmission format after March, 1987

SCC - Satellite Calibration Centre (of the ISCCP) in Lannion, France

SDAS - Satellite Data Archiving System, in CCAA, AES

SDL - Satellite Data Laboratory (formerly in ARMA, AES)

VIS - Visual

WMO - World Meteorological Organization